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WITH FIVE PLATES

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CITY OF WASHINGTON
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INFECTION AND RECOVERY FROM INFECTION[1]

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(With Five Plates)

Mr. Secretary, Ladies and Gentlemen: I experience a peculiar pleasure in being chosen to deliver the Hamilton Lecture before the Smithsonian Institution, for, from its beginning, this Institution has been an instrument of catholicity in science, knowing no geographical or national limits and subserving no special department of learning. Its object has been to promote all science. My pleasure is derived from the admission of medicine, so long the healing art, into the body of the exact sciences, into which it has been carried by the discoveries in anatomy, physiology, and pathology of the last decades.

The most notable advances that have thus far been made in the medical sciences relate to the discovery of the class of infectious diseases and the mode of their conquest. Infectious diseases are those diseases that are caused by the entrance into and multiplication within the body of minute, so-called microscopic, parasitic living beings. All animals and plants are subject to disease from this source. Our theme relates to the infectious diseases of the higher animals, and of man in particular, and the biological phenomena involved in recovery from them. Probably the identical or closely similar phenomena account for the recovery from infection of all orders of living beings.

Disease-producing parasites belong to the two great classes of living things; namely, animal and vegetable. The greater number now known are vegetable in nature and are included among the bacteria, but a large number also are animals and of protozoal nature. Just as there are harmless and even useful protozoa that never under any circumstances act as causes of disease, so there are many bacteria of similar innocuous or useful habits.

[1] Lecture delivered at Washington, D. C., February 8, 1912, under the auspices of the Hamilton Fund of the Smithsonian Institution.

In spite of their minute size, these visible parasites possess characters that permit in most instances of their ready identification by the microscope. The small number that lack distinguishing characters of form may be identified by their physiological properties when cultivated in broth or otherwise outside the body; a very few demand for identification the test of disease-producing capacity in animals.

But we are beginning to learn that not all minute organisms can be rendered visible by our most powerful microscopes, and a number of serious diseases of the higher animals, including man, and one disease of plants (the mosaic disease of tobacco) are caused by submicroscopic parasites. It is, indeed, not remarkable that the present microscopes should have failed to define the limits of organized nature. Whether we shall ever invent instruments capable of resolving and rendering visible these minute particles of living matter is a question impossible to answer. Even doubling the potential power of the microscope, by the device of employing for photographic purposes the ultra-violet rays of the spectrum, has failed to bring them into view. Their place in nature is not accurately established. Some, as the parasite causing yellow fever, which passes a stage of its existence in mosquitoes, probably are protozoal; others, as the parasite of pleuropneumonia of cattle, which can be propagated in artificial cultures, probably are bacterial. It can hardly be doubted that they are living organisms, since they are capable of transmission from animal to animal, in which they produce infection, through an indefinite series. The last disease to be discovered to be caused by a submicroscopic parasite is epidemic poliomyelitis, or infantile paralysis. Because the submicroscopic parasites are too small to be retained by, but pass through fine earthenware filters, they have also been termed filterable organisms or viruses. No member of this class of organisms is now known, except such as cause disease.

It is a matter of common knowledge that all individuals of an animal species are not equally subject to disease. This observation can be made on every hand among the human species especially. Careful analysis has indicated that the condition of susceptibility to infection varies not only with the individual but also with the infection itself. Thus measles and small-pox are diseases to which every human being may be regarded as subject, while scarlet fever, diphtheria, epidemic meningitis, and poliomyelitis can claim far fewer victims. So among animals, a certain few diseases secure an almost universal dissemination once they are introduced; while others, the effects of which, after they become established, may be equally or even more severe, affect far fewer individuals. Beside this fact of varying individual susceptibility within a species is to be placed the highly significant one of racial distinction. All sheep, except the Algerian variety, are subject to anthrax infection; the Maltese goat readily becomes a reservoir of the coccus which it excretes in the milk, and which produces Malta or Mediterranean fever, while other species of goat do not. Certain strains of wheat are not subject to attack by the fungus that readily causes "rust" in other species, and this quality of susceptibility or the reverse is transmitted as a unit character. It is not known whether the phenomenon of susceptibility in animals depends also upon so sharp an hereditary factor.

Infection is an active process quite different from the mere presence upon a surface of the body of the parasite capable of causing disease. We carry constantly upon our skin and mucous membranes a whole host of potentially infectious bacteria which, for the most part, do no harm whatever, and possibly, indeed, through preoccupation of the soil, ward off at times more definitely and highly injurious parasites. And yet they are capable of malign activities. The whole large and important group of pus-producing bacteria are our constant guests, as are quite a number of other species, including the germ that causes pneumonia.

Thus we are obliged to conclude that the surfaces of the body exposed to constant bacterial action possess a high degree of insusceptibility to ordinary infections. This state, about which there can be no question, is spoken of as local immunity. It depends, moreover, on definite factors, some of a relatively coarse kind, that operate only as long as they may be intact, and fail to operate adequately when imperfect. The opening up of "portals of entry," as they are called, of bacteria into the body follows upon the breaking down of this system of external defensive mechanisms. Thus the mucous membrane of the nasal and buccal cavities, especially about the masses of lymphatic tissue called the tonsils, which are imperfectly provided with a complete epithelial investment, particularly in the young, constitutes the gateway into the body of the infectious agents causing diphtheria, measles, scarlet fever, epidemic meningitis, and probably poliomyelitis. These mucous membranes are, obviously, so directly exposed to wide fluctuations of temperature, degree of moisture and dust-content of the air, as to become the common seat of slight pathological conditions that depress their protective powers. That an intact epithelial investment acts as a barrier to certain of these infections is shown by the fact that an abraded skin surface may be the source of a diphtheric or scarlet fever infection.

The mere presence of highly invasive and infectious bacteria upon a mucous surface is not tantamount to infection. In every epidemic of disease, we either know or have reasons for believing that many more persons carry the germ of the disease than actually come down with it. Thus diphtheria bacilli and meningitis cocci—to mention two examples only—are, during epidemics of their respective affections, found in the throat and nose of many more healthy than diseased persons; and similarly during the prevalence of cholera, dysentery, and typhoid fever, the bacilli causing them are present in the intestinal tract of persons in health. And yet, while these healthy carriers of infection may escape illness altogether, they are often the means of transporting disease to other and susceptible persons who succumb to it.

The reason for this phenomenon is to be sought in an adequate system of external defensive mechanisms in the group resisting infection, and an inadequate system in the other acquiring it. That this is the true explanation is indicated by the effects of indiscretion in diet or the ingestion of irritating substances upon such a potential cholera case, for through these a healthy carrier may be transformed, in a few hours, into a severe and often hopeless case of cholera.

That the broken skin surfaces admit infection is common experience, but luckily the infections thus produced are relatively insignificant. And yet, as the result of injury or a surgical wound, they may be severe. There is, however, no difficulty in following such coarse phenomena as these instances present. It is somewhat more difficult to follow the more remote infections, from this source, that lead finally to tetanus, or lockjaw, or to hydrophobia. In the former, the spores of the tetanus germ, which are enduring and highly resistant bodies, are introduced into the wound with foreign matter—dirt, splinters of wood, wads of paper, etc.—and in the latter, the germ of hydrophobia is injected into the tissues by the bite of a rabid animal. In both instances, the infection develops slowly, often after the original wound is healed and perhaps forgotten. In neither case has the infecting organism power to penetrate the unbroken skin. In both, again, the infection attacks the central nervous system, to which it gains access by travelling along the peripheral nerves; and the seriousness of the respective diseases produced arises from this direct attack upon the important cells of the brain and spinal cord.

The injection of microörganisms into the blood by insects is a more subtile means of causing infection, and it is not only established beyond peradventure, but is of the highest possible significance. It may be stated that this discovery, as much as any other in the whole realm of preventive medicine, has determined the methods, already successfully invoked in many countries, of suppressing highly fatal forms of disease. The range of parasitic causes of disease known to be thus inoculated, as well as the insects that inoculate them, is wide. Mosquitoes carry malaria and yellow fever; biting flies carry trypanosome infections, including the deadly sleeping-sickness; ticks and bed-bugs carry spirochetal infections, including the severe and fatal African tick fever and relapsing fever; body lice carry typhus fever; and fleas carry plague. This list includes all classes of parasitic microörganisms. The protozoa are represented by the malarial parasites and trypanosomes, the bacteria by the plague bacilli, and the submicroscopic organisms by the cause of yellow fever.

Still other factors contribute to determine infection. The period of childhood is especially characterized by a class of infections that depend upon imperfections in the anatomical barriers that are far more adequate in adult life. Many of the diseases that we associate with childhood—measles, scarlet fever, diphtheria, epidemic meningitis, and poliomyelitis, already mentioned—utilize the mucous membranes of the nose and throat to gain a foothold in the body, because they are notably vulnerable. Their crypts or depressions afford a lodging place in which multiplication of the parasites can be effected, and the breaks in the epithelial covering constitute the first breach in the external defenses which the parasites seek to and successfully do enlarge. Tuberculosis of the lymphatic glands of the neck and of the bronchi occurs especially in the young, and also, because of the greater permeability of the corresponding mucous membranes, in children. The intestinal mucous membrane also is permeable to a greater degree for microbes in the young, and thus they are exposed far more than are adults to food infection with the tubercle bacillus. Moreover, the whole group of microbic infections of the stomach and intestines of children, which creates such sad havoc during the warm summer months, depends upon two things; smaller power of excluding germs by their mucous membranes, and a variety of food that is a highly perfect medium for varied microbic growth. In older persons, the incidence of typhoid fever ceases with the anatomical changes coming in the fourth decade of life, that reduce the absorbing power of the intestine for bacteria; while certain parasites, such as those causing cholera and dysentery, are not stayed by these conditions, but are themselves capable of producing damage, although being assisted by other injurious agencies.

At first sight, it appears paradoxical that very young infants should show, in view of these facts, a definite resistance to such a disease as measles. But the discrepancy finds an easy explanation in the immunity acquired from the mother, by passive transfer of the protective principles, first from the blood of the mother during pregnancy and later with the milk during nursing. This immunity, being but passive, soon disappears, and the child of a few years then becomes readily infectible. The milk is the one secretion that derives from the blood the immunity principles in large amount, in this differing from all other glandular secretions; and here the coincident permeability of the intestine in the young scores an advantage against the parasites, since they are absorbed from this source into the blood.

Not all parasites of the same species, whether bacterial, protozoal, or submicroscopic, are potentially equal as agents of infection. The quality of virulence, so-called, is of high importance. Not a few of the more common parasites vary greatly in virulence, from degrees that make them almost harmless to degrees that make them almost inconceivably potent. Many millions of non-virulent pneumococci may fail to affect a rabbit, and a single virulent pneumococcus may suffice to produce certain death. This state of virulence is determined in some instances by races of the parasite of particular quality, so that what is virulent for one animal is not necessarily virulent for another. Thus the pneumococcus culture, of which a single germ will set up fatal blood poisoning in the rabbit, may fail utterly, even when many millions are injected, to affect the far smaller guinea pig. Such races of the poliomyelitis virus have now been recognized. The human strain, so called because it is derived originally from human cases of the disease, has at first small power to cause infection in monkeys. By successive transfer from monkey to monkey, certain samples can be made to acquire a prodigious activity for them, due to conversion, by adaptation, into the monkey strain, which there are reasons for believing has now lost power to infect human beings.

These changes take place sometimes slowly and sometimes quickly; in the latter instance, they correspond to or suggest the appearance of "sports" or "mutants" among the higher animals or plants. They have doubtless a definite relation to the prevalence of epidemics of disease, the laws regulating which have still to be worked out. But most epidemic diseases exist at other periods as sporadic diseases; that is, diseases of occasional occurrence. This is true of such epidemic diseases as influenza, meningitis, poliomyelitis, bubonic plague, and many others. But when the particular conditions appear that make possible the transfer of the adapted infectious germs quickly from susceptible individual to susceptible individual, then epidemics tend to arise. The period of this rapid transfer tends to synchronize with certain seasons, so that temperature and other meteorologic conditions play a part, affecting probably the parasites less than the animal host. Thus epidemic meningitis prevails in the winter, doubtless because the nasopharynx is less well defended through the occurrence of colds, etc., than in warm weather. Accidental conditions attending seasons and climates may also play an important rôle in particular epidemics. The recent Manchurian epidemic of plague, which claimed in a few weeks no less than 45,000 victims, was started, doubtless, by infected marmots which were being trapped for their skins; but its spread and conversion into the deadly pneumonic disease was promoted, if not directly caused, by the rigors of the Manchurian winters and the primitive accommodations in railways and inns for the thousands of coolie trappers who were returning southward to their homes. It is a recent and gruesome story how the desperate and panic-stricken coolies, in a fruitless effort to escape death, carried far and wide the highly virulent infection.

At an earlier era, knowing nothing of microscopic life and the essential part it plays in epidemics of disease, and recognizing that these catastrophes were not entirely willful but arose and declined according to some measure of law, physicians imagined a mystical "genus epidemicus" which controlled the visitations of the scourge. Modern science has indeed exorcised this ancient demon; and although it has not yet determined with precision all the elements that enter into the phenomenon of epidemics, it has unravelled them in so far as to indicate that they relate not merely to parasites but even more to the habits and customs, the beliefs and superstitions of peoples, that are often quite as difficult and yet as necessary to alter and improve as it is to overcome the malign propensities of the parasites themselves.

I have indicated that the body possesses remarkable external defensive mechanisms against infection, and, therefore, in order that infection may be accomplished, these defenses must at some point be weakened and destroyed; and I have also sketched some of the means employed to penetrate this armor. It may be illuminating if I now cite an example, from experimental medicine, to show how important these external defenses are. Epidemic poliomyelitis, or infantile paralysis, is, as far as we know, a disease of human beings exclusively. The evidence available is to the effect that the microbic cause of the disease enters the body by means of the nose and throat and locates in the central nervous organs, where it multiplies and ultimately brings about the tissue changes that account for the paralysis and other symptoms. Of the lower animals, monkeys alone are really susceptible to the disease, but only upon inoculation. They never take the disease spontaneously; that is, they can be exposed to the infection in any degree and yet they remain free from it. But when the cause of the disease, in most minute quantity, is made to pass the external defenses, by being inoculated into the nervous system or into the interior of the nasal mucous membrane, they not only acquire poliomyelitis, but they develop a far severer form than occurs spontaneously in human beings. The deduction from this fact is that monkeys, as compared with human beings, possess a far more efficient system of external mechanisms to exclude the poliomyelitic virus; but human beings, as compared with monkeys, possess a far more efficient internal agency of destruction for the virus, after it has gained access to the interior of the body.

But for the existence of this second line of defenses, the internal, as we may call it, the infected body would be wholly at the mercy of invading parasitic causes of disease. But this second line is, indeed, even more efficient than the first, and of more varied potentialities. It consists of a group of substances contained within the blood, but not produced there, and passing from the blood into the lymph, where they exert influence on the cells composing the organs and upon parasites in the interstices of the tissue. The chief site of the production of these protective and healing principles—immunity principles, so-called—is the very place where the blood corpuscles themselves are formed; namely, in the bone-marrow, spleen, and lymphatic glands. The principles are divisible into two classes of substances: one soluble and dissolved in the fluid plasma, and the other corpuscular and suspended in it. The latter consists of the motile white cells or phagocytes; and together, in virtue of their soluble form and ready motility, they are able quickly to reach most parts of the body where their peculiar properties may be exerted. Not only are these immunity principles preformed in all individuals in whom they operate against intending infections, but they become rapidly increased when infection has been established; and the ultimate issue of the condition in spontaneous recovery or the reverse depends upon the degree of this response and the competency of the curative bodies evoked to reach and to suppress the infectious agents.

The normal body possesses, therefore, great potential power of resisting infection, and this power can be quickly raised, on demand, to a higher level, so as to ward off disease through a rapid augmentation in the number of circulating white corpuscles or phagocytes, and by means of an increase in the dissolved principles, the purpose of which is to act upon and injure the parasites and to neutralize their toxic or poisonous products. This process is either identical with or closely related to that which takes place during recovery from infection, which consists in the bringing into being of a new set of operations that gradually reinforce the natural resistance—a process termed immunization. The indications of the immune condition are found in the appearance in the blood sometime between the fourth or fifth and the tenth day of the disease, and somewhat later than they have appeared in the spleen and bone-marrow, of highly potent substances that are directed in a specific manner to the direct neutralization of the poisons which have been and are still being produced by the parasites, and to the destruction of the parasites themselves through heightened phagocytosis. As recovery progresses, the soluble immunity principles continue to increase, until, at the termination of the disease, they are present in the blood in quantities that suffice, often, by a passive transfer to another individual, to protect him more certainly from infection or to terminate abruptly an infection already established. If, in imagination, we substitute for man a large animal, such as the horse, and if we conceive the immunization process to be carried forward by design and in a manner to cause the minimum of damage and to produce the maximum of immunity response, we have presented to our mind's eye the principles as well as the method upon which the serum treatment of disease is based.

I should like to emphasize, at this point, the fact that the foundation of the modern specific treatment of infectious disease by serums, by inoculation of dead bacteria, and even by specific chemical compounds, rests upon the working out in laboratories, upon animals and man, of the manner in which spontaneous recovery from disease takes place. I need not remind you that the leading physicians rarely failed to appreciate the unexcelled power of nature to heal her self-inflicted wounds and to recognize that many diseases tend of themselves to progress toward recovery. It has been through imitation of nature's way of curing disease that the efforts at modern control have been forwarded.

With factors so various, it is obvious that conditions which cannot always be followed must make for and against infection. This is the element in the problem that is popularly termed "chance" ; and yet this audience need not be told that the term is a mere euphemism for ignorance. Coincidences and probabilities are among the common factors of infection. It is not chance, but ignorance or indifference that carries a free person into a plague infested region; and once there it is fleas and not chance that decide whether he shall or shall not acquire plague. No more is it chance, but only augmented susceptibility, that causes one disease to play into the hands of another, and that decides that the victim of measles, scarlet fever, or smallpox shall succumb to a streptococcal pneumonia or blood infection to which those diseases render him morbidly liable; and no more is it chance that the bearer of a severely damaged heart or kidney or liver shall finally be overcome by a terminal bacterial infection. What the flea has determined for the plague, the diseases predisposing to infection with the pus-producing bacteria accomplish by damaging the body's external and internal defenses against this ubiquitous class of microbic parasites, that ever lurk about seeking opportunity to invade and propagate within the blood and tissues.

So, as we have seen, medicine has advanced from empiricism and become scientific, as chemistry and physics have advanced from alchemy, and astronomy from astrology, and become scientific, by rigid experimental investigation and controlled, logical observation, until now the domain of knowledge is differentiated from the domain of ignorance and superstition by a vigorous body of ascertained truths and established methods of research that rest neither on authority nor opinion. The tangible gains have been such perfected means of combating disease as are represented by the specific serums that have reduced the mortality from diphtheria and epidemic meningitis to one-fourth of the spontaneous recovery rates, the dangers from tetanus and hydrophobia from infected wounds, by means of protective injections, almost to zero, and through preventive inoculation the liability to typhoid fever to a vanishing figure. And thus it has also been achieved that the discovery of specific chemical means of suppressing disease is no longer left to the heart-breaking method of finding useful drugs, in the manner that quinine and mercury were found, by an infinite series of tests upon suffering human beings, based upon pure accident, but by following ascertained clues, first in the laboratory upon the lower animals, until by a process of selection and perfection, such remarkable instruments for the control of serious diseases as salvarsan shall have been evolved.

But the problem is not solved with the discovery of a specific serum or chemical, since these perfected agents must act within the body upon the parasitic causes of disease that seek in different ways to escape their influence. Whether the parasites have a general distribution throughout the blood and tissues, or whether they are confined within a pathological formation in the interior of an important organ or part, and whether they can resist by mutational alterations the action of the curative agents, may be the factors that determine whether the native curative principles or the extraneous ones shall gain access to the seat of disease and bring about their suppression.

In its struggle to survive, the parasite withdraws sometimes into situations to which the curative substances gain access imperfectly and with difficulty. This is the condition present in local infections more or less cut off from the general circulation and from the curative principles purveyed by the blood and met with in the great serous cavities, and especially in the cavity within the membranes that surround the central nervous system. The cerebrospinal fluid is a remarkable liquid that may be regarded as the " lymph " or nutrient medium of the central nervous system; and yet it is almost devoid of protein matter. Now, as it is the protein matter that carries the immunity and healing principles, it follows that the subarachnoid spaces of the central nervous system are dangerously free from them. Moreover, since the anatomical structure decides the quality of the lymphatic fluid in health, it also determines it in disease, and thus it follows that parasites that become localized in the cerebrospinal membranes, for example, are insured a potential advantage against the host. And these general facts are applicable, if in somewhat less degree, to parasites that become established in the cavity about the heart, the lungs, and the abdominal viscera, as well as the spaces about the joints.

Again, certain parasites possess a power of regulation within themselves that serves, often, to protect them from extinction. Under the influence of specific serums or drugs, they undergo a subtile change, probably chiefly of a chemical nature, through which they acquire a capacity of effective resistance to the curative agent. This state is called " fastness " and is regarded as a kind of mutation equivalent to the sudden formation of " sports " and new species among the higher plants and animals. The acquired characters of fastness have been observed to be transmitted by certain orders of parasites through indefinite generations. Our knowledge of this state is derived chiefly from the study of trypanosomes and spirochetal organisms; but it arises among bacteria also. It persists in the protozoal trypanosomes only as long as they continue to multiply asexually in the blood of infected animals, and disappears as soon as the normal state is reëstablished, when the organisms multiply sexually, as is their habit, in the body of insect parasites of the host, as, for example, the rat-louse. Bacterial fastness, on the other hand, tends to disappear when these parasites are cultivated artificially outside the body. The particular significance of this resistant state grows out of the circumstance that it is coming to be held accountable for the troublesome or dangerous relapses that occur in many of the infectious diseases.

Manifestly the two factors of location and mutation will determine, in no small degree, the effectiveness of the operation of specific substances for treating disease. When the cause of disease is widely disseminated in the blood, as in malaria, or when it is in the nature of a chemical poison, as in diphtheria, it will obviously readily come under the influence of the curative principles; but when the infecting microörganism takes up a position in the interior of a massive pathological formation, or in the crebrospinal membranes, for example, the organism will be more difficult to reach and affect. By applying, however, the specific therapeutic agent directly to the seat of the disease, as is being done in the serum treatment of epidemic meningitis, this obstacle to success is being removed.

Bacteriology as a science may be reckoned as dating from the overthrow of the spontaneous generationists and the discovery by Pasteur of the cause of *pébrine* among silkworms. It was quickened into active life and brought down to every-day use, and thus immeasurably extended, by Koch. We are, as it were, still living within the era of its first achievements, and thus we may reasonably hope that this is merely the dawn of its beneficent triumphs.

EXPLANATION OF PLATES

Plate 1

Fig. 1. Bacillus of typhoid fever. A common rod-shaped bacterial type.

Fig. 2. Pneumococcus, the cause of acute pneumonia, mingled with white blood corpuscles (phagocytes). From an infected mouse.

Plate 2

Fig. 1. Meningococcus, the cause of epidemic cerebrospinal meningitis. It is characteristic of this coccus to be within the white corpuscles or phagocytes.

Fig. 2. Spirocheta of African tick fever. In the blood of an infected mouse.

Plate 3

Fig. 1. Ticks that carry and inoculate the spiral microörganism of African tick fever.

Fig. 2. Tsetse fly that carries and inoculates the trypanosome of sleeping sickness.

Plate 4

Fig. 1. Trypanosomes. A protozoal parasite causing diseases of animals and the sleeping sickness of man in the tropics.

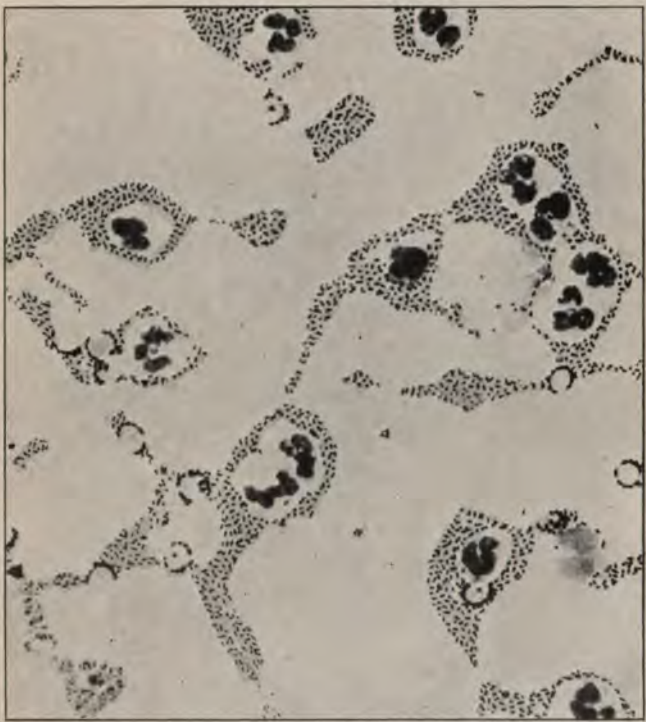
Fig. 2. *Spirocheta pallida* in artificial culture. The microörganismal cause of syphilis.

Plate 5

Fig. 1. *Spirocheta pallida* in the liver of a new-born infant (diagrammatic). The intimate association of parasites and tissue cells is shown. It is the purpose of a specific curative substance to destroy the former without injuring the latter.

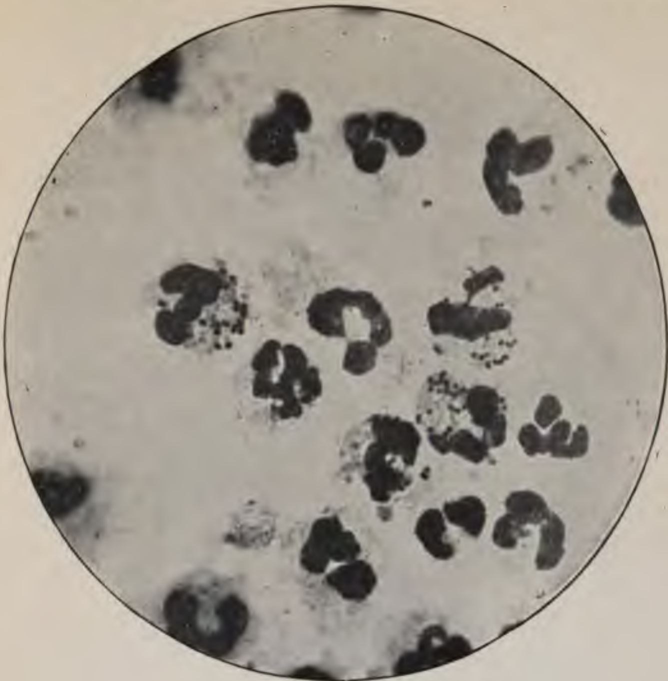
Fig. 2. Chart prepared by Dr. Dunn, of Boston, to show the effect of the antimeningitis serum on the mortality from epidemic meningitis in the Children's Hospital, Boston. The serum treatment was introduced in 1906 at the point indicated by the cross (X).

1. BACILLUS OF TYPHOID FEVER

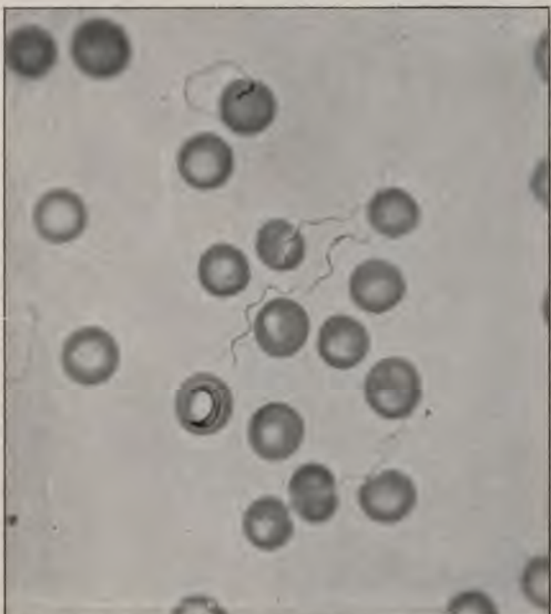


2. PNEUMOCOCCUS AND PHAGOCYTES

SEE EXPLANATION OF PLATE



1. MENINGOCOCCUS
SEE EXPLANATION OF PLATE



2. SPIROCHETA OF AFRICAN TICK FEVER, IN BLOOD OF INFECTED MOUSE

1. TICKS THAT CARRY AND INOCULATE SPIRAL MICROÖRGANISMS OF AFRICAN TICK FEVER

2. A TSETSE FLY THAT CARRIES AND INOCULATES THE TRYPANOSOME OF SLEEPING SICKNESS

1. TRYPANOSOMES OF SLEEPING SICKNESS

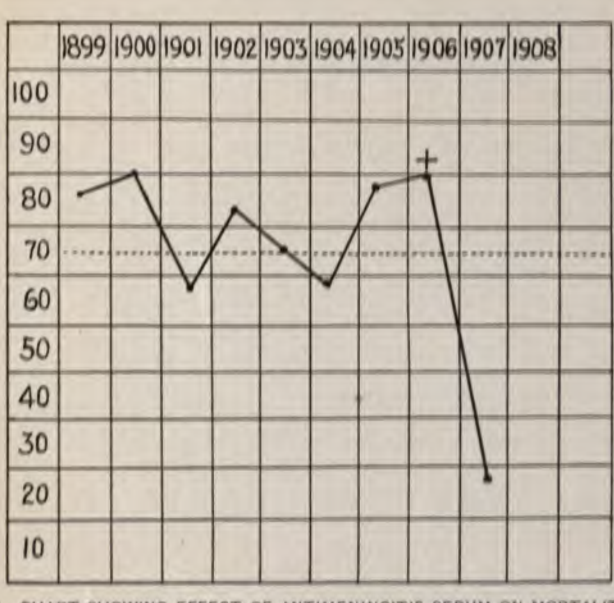
SEE EXPLANATION OF PLATE

2. SPIROCHETA PALLIDA IN ARTIFICIAL CULTURE

SEE EXPLANATION OF PLATE

1. SPIROCHETA PALLIDA IN LIVER OF NEW BORN INFANT

SEE EXPLANATION OF PLATE



2. CHART SHOWING EFFECT OF ANTIMENINGITIS SERUM ON MORTALITY FROM EPIDEMIC MENINGITIS IN CHILDREN'S HOSPITAL, BOSTON. SERUM TREATMENT INTRODUCED IN 1906 AT POINT INDICATED BY CROSS (+)

SEE EXPLANATION OF PLATE